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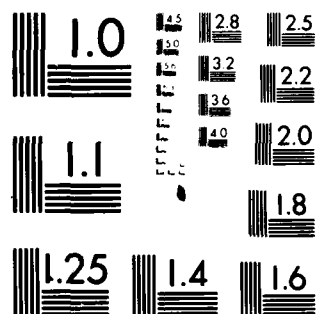
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Proposed Research Tasks
for the
Reduction of Human Error
in
Naval Aviation Mishaps

Donald M. Layton
October 1981

Final Report for Period July 1980 - September 1981

Approved for public release; distribution unlimited

Prepared for:
Commanding Officer, Naval Aerospace Medical Research
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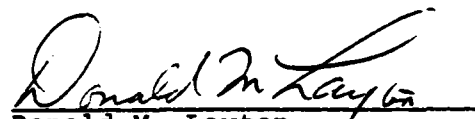
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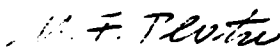
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I. INTRODUCTION

At any time, the loss or damage to a naval aircraft is a most serious matter with severe impact on dwindling resources, this problem is greatly magnified. Much effort has been devoted to the improvement of aircraft hardware in an effort to reduce the military accident rate and its consequences. An insidious problem exists, however, that can negate many of the advances that have been made in the material areas - the problem of the human factors involvement in aircraft mishaps.

In discussing this problem there may be a tendency to become mired down by the semantics of the terms 'Human Error' and 'Human Factors'. The former term usually denotes an error of commission or of omission, including time-dependent functions, and, in general, tends to exclude the problems that arise when a function can not be performed (or can not be performed in a correct or total manner) due to a secondary cause such as location, interference, et cetera. For this reason, all personnel involvement patterns are frequently collated under the generic title of 'Human Factors', even though this term is sometimes reserved for the analysis of the human endeavor. Rather than depend on detailed and definitive definitions, this report will use the term 'Human Factors' to denote all types of personnel actions.

The rising toll of Human Factors involvement in Naval aviation mishaps clearly indicates that some action be taken to reduce this trend. However, prior to undertaking some

costly, and perhaps fruitless, programs, it is wise to consider the entire arena of Human Factors in an effort to determine the most cost effective plans of action. This effectiveness must be measured not only in the dollar cost of such research and the resultant improvement programs, but must also include the negative utility of the continuation, and possible growth, of the problem if no action is taken.

A simplified statement of the immediate problem, therefore, may be made as follows:

"Are there specific areas of research into Human Factors involvement in Naval aircraft mishaps that indicate a positive pay-off in terms of mishap reduction and/or amelioration?"

There are two general methods of approaching both the problem and the potential solutions. The first of these might be termed the "Band-Aid" approach wherein after-the-fact fixes are applied following mishaps in an effort to prevent the recurrence of the problems. For many years this technique has been espoused by the Navy (and the other services) and, despite many drawbacks, has enjoyed a fair degree of success. The establishment of the Naval Aviation Safety Center in the early 1950's was for the purpose of reducing an extremely high aircraft accident rate through the means of education and product improvement recommendations. Although it might be argued that at least some of the dramatic reduction in the aircraft accident rate has been due to modification of the scorekeeping techniques, it can not be denied that not only has the accident rate been reduced but also

there has been an improvement in the mission effectiveness of Naval aviation due to the reduction of lost and damaged aircraft. From the Human Factors standpoint, however, many of the product improvement programs involved the fitting of the man to the machine, rather than the other way around.

In the mid-1960's, the military undertook several programs under the name of the System Safety, wherein definitive actions were required to design safety into the weapon systems. These programs, which are currently codified under the Military Standard 882A, "System Safety Program Requirements", a document providing for the inclusions of System Safety practices into the entire life cycle of weapon systems. Although MIL STD 882A requires hazard identification, hazard analyses, risk assessment and elimination or control of high critically risks, this standard provides minimal guidance in the Human Factors arena.

Specific requirements relating to Human Factors are to be found in MIL STD 1472, "Human Engineering Design Criteria for Military Systems, Equipment and Facilities", and the Specification, MIL-H-4685B, "Human Engineering Requirements for Military Systems, Equipment and Facilities". These documents are required to be applied during development and acquisition of military systems, equipment and facilities to achieve the effective integration of personnel into the design of the system. An engineering effort is required in order to provide the development or improvement of the crew-

equipment/software interface and to achieve the required effectiveness of human performance during system operation/maintenance/control.

In all design or re-design functions, the essence of safety integration is hazard analysis, and in all types of hazard analyses, the first step is applying the lessons learned from previous systems. This requires that some type of data bank be available, that this data bank be as complete in the areas of the search as possible, and that complete investigation and evaluation of this data bank is performed. In the arena of Human Factors involvement in Naval aviation mishaps, this data bank consists, almost exclusively, of information reported under the Navy's OPNAV Instruction 3750.6 series under the auspices of the Naval Safety Center. For this information to be effective in hazard analyses, it is necessary for these data to be: (a) reported properly; (b) evaluated thoroughly; (c) 'coded' into machine language for storage in such a manner that all variations and perturbations may be extracted from storage; and (d) capable of cross-correlation for the purposes of trend analysis.

The standard procedure for the development of a report in accordance with the 3750.6 series of instructions is for the mishap report to be generated by a local investigation board with assistance, when available, from a Naval Flight Surgeon, forwarded through the military chain command to the Naval Safety Center, evaluated for Human Factors involvement

by the Aero-Medical Department, and inserted into the machine records by coders with little or no training or background in Human Factors. This procedure, although necessary due to resource utilization, raises a question as to the completeness of the data as they relate to Human Factors.

Another, and potentially even more serious, problem in the development of Human Factors data lies in the fact that, except for somewhat random submittal of material not normally reportable under the 3750.6 series, e.g., "Anymouse Reports", there is little information available concerning those problems that have not yet caused reportable mishaps. Although a mishap is an undeniable proof of probability, it is most ineffective from a resource utilization viewpoint.

One approach to the previously stated problem would be to examine in considerable detail what has caused Human Factors mishaps in the past, what current problems exist that might cause problems in the immediate future, and how all such problems may be prevented by proper aircraft design and/or enhanced operator evaluation and education. However, inasmuch as this report is for the purpose of recommending specific research activities to alleviate Human Factors involvement in Naval aviation, it has been decided by the author to develop a matrix with a base of where such research activity should be applied rather than using the type of research as a base. A simplified statement of the Approach to the Problem is, therefore:

"Recommend various areas of research that might best be accomplished by: (a) In-house activity of the Naval Medical Research Command; (b) In-house activity of 'other Navy'; and (c) contracted research activities."

The following sections of this report are aligned along the lines of this approach.

II. IN-HOUSE - NAVAL MEDICAL RESEARCH COMMAND

A. TASK 1.1

One of the very first steps to be taken in an effort to define the problem should be an in-depth examination of existing files and records. It is stipulated that the aviation mishaps reported under the OPNAV 3750.6 series have had the advantage of immediate post-mishap investigation and analysis and that additional examination of these records and files at this time will suffer from the 'second-hand' nature of the investigation. It is a fact, however, that the original investigations rarely had the services of personnel trained and educated specifically in the Human Factors arena, such are to be found in the Naval Medical Research Command.

It is recommended that the following procedures be established for this effort:

1. Request separate listings from the Naval Safety Center of all aircraft mishaps for the past five (5) years with (a) personnel as Primary causal factors and (b) personnel as Contributory causal factors.
2. For those mishaps listed with personnel as Primary causal factor, make a representative (say, one in ten) examination of the actual reports to verify the coded findings. Based on the satisfaction with this partial survey, make additional in-depth examinations, as desired.
3. For those mishap files with personnel listed as Contributory causal factor, examine all of the actual records

to learn if training, man-machine interface and/or design factors were present.

It is roughly estimated that the above examinations would take approximately four (4) man-months effort on the part of a human factors specialist including familiarization with the coding and machine language that is in use. A major portion of this time would have to be spent on-site at the Naval Safety Center, Norfolk, Virginia because of the availability of the records.

The data obtained from these examinations should be correlated into sub-causal factor arrangements, and, if criticality can be determined, into a risk assessment order. It is realized that, due to the low population of the statistic, determination of probability will be difficult, but a propbability based on the overall mishap record could be used.

If these data are judged to be significant, it is recommended that they be augmented by data from the Directorate of Aerospace Safety (Air Force) and the Army Safety Center to increase the size of the statistic. Because of the differences in aircraft types and mission employments, these data may not be of special significance to the study. It is from this reason that this examination should be conducted by a trained Human Factors professional, rather than by a 'clerk'.

The short term goal of this research phase is to ascertain what Human Factors elements have contributed to military

aviation mishaps in the immediate past. The long term goal is, of course, the elimination or control of these types of mishaps. To achieve this end it will be necessary to conduct an analysis and evaluation of the various mishap prevention techniques that may be available. These will include new design, re-design, standardization of design and general and/or specific operator training and education programs.

It is estimated that after the initial collection of data, the remainder of this research task will involve approximately two man-years of effort.

B. TASK 1.2

The most involved of the human operator functions in military aviation is the task of the aircraft pilot. Paradoxically, the single item that may be of the most assistance to the pilot is the design of the cockpit/instrumentation, while the single factor that may be of the most detriment is also the cockpit/instrumentation design. As the vehicles and their missions become more complex, so does the cockpit environment.

The aircraft in the Navy inventory have had various degrees of human factor engineering in the design of the cockpit systems. In the most cases, however, this activity has occurred early in the design cycle and has been conducted by specialists in human factors with little input for the operational community. In addition, many of the original design stages, production and/or modifications because of

other considerations. There have been but very few instances where a follow-up was made to ascertain if what is actually incorporated in the cockpit system is optimal for routine and emergency use. To use a management analogy, the initial design was a result of Operations Research and the proposed follow-up is Operations Analysis.

It is recommended that the following procedure be established for this Task:

1. Establish a cockpit review committee consisting of both human factors specialists and operational pilots.
2. Establish a cockpit system review procedure for both routine and selected emergency procedures. This procedure should include qualitative and quantitative reviews of responses, reactions and the time measurements of the responses.
3. Conduct these reviews in a current simulator or Operational Flight Trainer (OFT) of a first line, high performance aircraft. If resources permit this review to be performed on more than one aircraft, it is recommended that a fighter and a patrol aircraft be investigated. If only one aircraft can be examined, it is recommended that it be a fighter, with the suggestion that it be an F-18 because of the great amount of human factors effort that was put into this aircraft. This would permit a meaningful follow-up.

It is estimated that this procedure, after the establishment of the ground rules, would involve approximately two-man years of effort.

C. TASK 1.3

The fitting of the machine to the man is based on average anthropometric data which, in some instances, is out of date. The development of a cockpit system that accommodates the 5 to 95 percentile pilot/crewman is based on best available information, but one has only to look at high school graduation photos, college and professional athletes, and the increasing number of females in Navy cockpits to realize that sizes have changed drastically over the last ten to twenty years. As a result, the standardized anthropometrical data needs to be re-examined.

It is therefore recommended that:

1. The standard anthropometrical data be examined in relationship to the current averages to determine if changes in the standard should be made.
2. The physical records of entries into the Navy flight training program should provide an excellent source of current data.

Review of the current data and correlation to the anthropometric data would probably require approximately one-half man-year of effort.

III. IN-HOUSE - OTHER NAVY

A. TASK 2.1

The only ready source of potential human factor involvement in aircraft mishaps is the after-the-fact mishaps reported through the OPNAV 3750.6 series of instructions. Many serious deficiencies go unreported because of the minor nature of the mishap result, because of 'cover up' or because the deficiency did not result in a mishap. One needs only to attend a Happy Hour with fleet pilots to hear tales of occurrences that have never reached the publishing listings.

Although the Navy's "Anymouse" program was designed to gather information about unreported events, these reports only scratch the surface. It is possible to increase the scope and depth of these reports by conducting a fleet wide survey using questionnaires, it has been found* that this procedure is not as satisfactory as the interview format called "Critical Incident Technique", as developed by Fitts and Jones (Wright-Patterson Air Force Base, circa 1947) and Tarrant.

This technique may be summarized as follows:

1. A group of pilots is selected and informed of the study and its objectives. They are permitted to withdraw from participation if they so desire.

*W. E. Tarrant, "Utilizing the Critical Incident Technique for Identifying Potential Accident Causes", (Washington, DC, U. S. Department of Labor).

2. The interview is conducted one-on-one by a trained interviewer who presents the participant with a short list of typical incidents to stimulate the recall process.

3. Participants are asked to describe any incidents that they might recall, whether or not they had resulted in mishaps. They are also asked whether they recall any such incidents that occurred to theirs.

4. Questioning is continued until human errors or unsafe conditions in any recalled incident can be described. Recording of the information is by the interviewer.

One of the problems with the Critical Incident Technique is that it requires a trained interviewer. The necessary training, however, is not complex, and the Aviation Safety Officer in a squadron or Wing staff could be trained.

A typical program was conducted at the Naval Postgraduate School in March 1976 as a Master of Science Thesis by CDR Gene L. Daniels, USN, under the supervision of Professors Waldeisen and Neil.

An opportunity to establish such a program and train potential interviewers lies in the courses conducted by the Aviation Safety Programs at the Naval Postgraduate School. This activity conducts six-week short courses in flight safety for squadron and staff safety officers and ten-day short courses for command and senior staff personnel. The graduate of the Aviation Safety Officer (ASO) courses go to or return to fleet activities as flight safety officer. Not

only are these people well trained and motivated, they are in fact, looking for safety projects to conduct upon their return.

It is recommended that the following procedure be established:

1. Establish liaison with the Director, Aviation Safety Programs, Naval Postgraduate School, Monterey, California for permission to conduct interviewer training during the ASO curriculum periods.

2. Develop the interview form and the interviewer training syllabus.

3. Have the ASO conduct the Critical Incident Technique interviews in his squadron upon his return.

4. Provide for correlation and review of the completed forms.

This program would require the part-time service of one person, e.g., a Naval Postgraduate School faculty member, for the training and report correlation. It is estimated that this would require funding for from one-half to one Academic Quarter for this faculty member for his services each year.

B. TASK 2.2

In addition to the Navy Medical Research activities, there are several other centers of excellence in human factors and the relationship of the operator to the aircraft. These include the Naval Air Development Center (NADC) and the Naval Air Test Center (NATC). NADC has involvement in the

aircraft during the design and engineering phases of the life cycle, and NATC has the first look at new production aircraft. There has been little connection in the past between these two groups.

It is recommended that a specific charter be drawn up that would marry the design expertise of NADC personnel to the operational test and evaluation expertise of NATC. This charter would direct a review (NATC) and analysis (NADC) of potential human factors problems in the test and evaluation of new aircraft.

The scope of such a research program, and its cost, would have to be the subject of negotiation between NADC, NATC and NAMRL.

The payoff of this program would lie in the early, i.e., pre-fleet deployment, detection of the problem areas. In addition, such a relationship between NADC and NATC would provide direct inputs to the NADC personnel for future design participation.

IV. CONTRACTED ACTIVITIES

A. TASK 3.1

All of the research tasks previously discussed have been addressed in an attempt to correct problems. There are several approaches looking at a definition of the basic cause of human factor errors in an effort to solving the causes rather than correcting their outcomes.

These activities are being conducted in industry, research laboratories and in universities and many of these programs need direct Navy support to enhance the probability of success. This Navy support is not only in the form of funding, which is always required, but also in the form of making available data and facilities.

A prime example of this type of research is that being conducted by Dr. Donald A. Norman, Center for Human Information Processing, University of California - San Diego, La Jolla, California 92093. Dr. Norman, who has been funded by the Office of Naval Research, has been investigating the basic causes of human error. He has done considerable research with some definitive results into the causes of repetitive errors among highly trained persons, e.g., typists. He has also done some investigation into causes of pilot errors, but has been hampered by the lack of test subjects. With the current, and proposed, funding support by ONR, Dr. Norman does not require direct support at the present, but if arrangements were made for him to gather

fleet data, say from simulator operations at near-by Naval Air Station, Miramar, his work might have an immediate payoff to the human factor mishap problem.

B. TASK 3.2

There are many other research activities that could use varying amounts of support to direct or to continue their activities as to human factor mishaps in Naval aviation. Typical of these organizations is the following list gleaned from a report of the North Atlantic Treaty Organization Advisory Group for Aerospace Research and Development (AGARD) report of the technical symposium "Problems of the Cockpit Environment", (November 1968).

Calspan, Buffalo, NY

Federal Aviation Administration, Washington, DC

Litton Systems, Guidance and Control Division,
Woodland Hills, CA

U. S. Army Natick Laboratories, Natick, MA

U. S. Air Force Aerospace Medical Research

Laboratories, Wright-Patterson Air Force Base, OH

Human Factors Research, Inc., Goleta, CA

While it is begging the premise of this report to suggest that one looks elsewhere for research opportunities, there are countless numbers of personnel who have involvement in human factors research who are generally not known until they are found. One source of these individuals and organizations is through professional societies, such

as the Human Factors Society. Another source is through trade journals and newsletters such as Aviation Week, Aviation Daily, and the Federal Register.

It is also possible to gather names of researchers in the field from publications of those who might already be known. For example, in his report "Errors in Human Performance" (Report No. 8008, Aug 80), Dr. Norman has three pages of references and a distribution list of approximately 180 names/activities. (One copy was sent to Dr. Roger W. Remington, Code L52, NAMRL.)

V. SUMMARY OF RECOMMENDATIONS

The following research actions have been recommended:

TASK NO.	ACTIVITY	TASK
1.1	NAMRL	Review of existing mishap reports
1.2	NAMRL	Cockpit review/analysis of existing Aircraft
1.3	NAMRL	Review and revision of standard anthropometrical data
2.1	NPS/Fleet	Critical Incident Technique
2.2	NADC/NATC	Design/T&E cooperation procedures
3.1	Industry	Basic research into error causes
3.2	Industry	Broad research functions

To optimize the pay-off of these human factors research activities, the following priority list is recommended:

PRIORITY	TASK NO.
1	1.1
2	2.1
3	1.3
4	1.2
5	3.1
6	2.1
7	3.2

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